Sediment Waves and Gullies Generated by Turbidity Currents

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LONG-TERM GOAL

The main goal of this investigation is to test the hypothesis that turbidity currents might be able of producing sand waves resembling anti-dunes and evenly-spaced gullies, such those revealed by recent surveys off northern California, on the sea floor and preserved within continental slope deposits (Spinelli and Field, 2001).

OBJECTIVES

Our objective is to improve our understanding of the genesis of large-scale bed forms similar to those observed in various submarine settings, and thought to be created by both confined and laterally-spreading turbidity currents and related dense underflows in continental slopes and rises. Two types of bed forms are the main focus of this work. First, slope gullies, which are parallel, evenly-spaced channels with typical relieves of the order of 1-5 m and separations ranging from 100 to 500m, found in most continental slopes around the world. Second, large-scale sediment waves (wavelengths 500-5000 m) surveyed in continental rises, on levees of deep-sea channels, and on the flanks of submarine canyons and submarine fans, which appear as upslope-migrating antidunes in the vast majority of observed cases.

APPROACH

Our approach has consisted of a combination of linear stability analysis, numerical modeling, and laboratory experiments. Numerical experiments have been conducted using layer-averaged conservation equations for turbidity currents (Parker et al., 1986), together with a simple, rule-based cellular model (Murray & Paola, 1994). The model simulates qualitatively the incipient formation of aggradational gullies on sloping sediment beds. Laboratory experiments, performed in the MARGINS TANK built under the STRATAFORM Program, have shown so far that conservative density currents and depositional turbidity currents are capable to develop bedforms at different scales such as dunes and ripples, as well as long-wavelength antidune-like sediment waves (Fedele and Garcia, 2001).

WORK COMPLETED

Linear stability analysis has been completed using conservative density currents capable of transporting sediment as bedload as well as erosional turbidity currents. Comparison of maximum

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14. ABSTRACT
The main goal of this investigation is to test the hypothesis that turbidity currents might be able of producing sand waves resembling anti-dunes and evenly-spaced gullies, such those revealed by recent surveys off northern California, on the sea floor and preserved within continental slope deposits (Spinelli and Field, 2001).

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growth rate curves for the above mentioned cases, as function of Richardson number, show that turbidity currents tend to form longer sediment waves than those associated with conservative density currents with bedload transport only. The analysis has been extended to account for the role played by the flow turbulence in the development of bedforms.

All the laboratory experiments have been completed for: a) wide turbidity currents emanating from a line source and producing incipient gullies, and b) channelized turbidity currents generating a range of bedforms from ripples to dunes and antidunes.

RESULTS

Results from the stability analysis indicate that both conservative and non-conservative supercritical dense underflows are able to develop long-sediment waves that migrate upslope (antidune type), and which might be possibly related to current interface instabilities (Fedele and Garcia, 2001). Figure 1 shows the components of the complex celerity of bed perturbations, as a function of wavenumber, for a density current. In this figure, growth rate (C_I) indicates that long sediment waves are, according to this analysis, likely to develop, whereas the celerity C_R indicates an upstream migration for these bed instabilities.

Laboratory experiments have shown so far that conservative density currents and depositional turbidity currents are capable of developing bedforms at different scales such as dunes and ripples, as well as long-wavelength antidune-like sediment waves (Fedele and Garcia, 2001). Figure 2 presents a spatial spectrum obtained from measured longitudinal profiles on a wide channel with movable bed, where successive turbidity currents were run. The two peaks marked on the plot in Figure 2 are associated with (a) upstream-migrating long-sediment waves ($\lambda \approx 0.65$ m), and (b) downstream-migrating ripples ($\lambda \approx 0.08$ m). Figure 3 shows filtered longitudinal bed profiles for two successive turbidity currents. Upstream migration of the long waves is evident in Figure 3. Figure 4, on the other hand, shows superimposed, downstream migrating ripples, resulting from the same series of turbidity currents.

It has been found that ripple geometry and migration rates are functions of the relative position of each small bedform, respect to the long antidune, indicating interaction between interface instabilities, bed instabilities, and the mechanics of sediment transport for these underflows. Finally, transverse (filtered) profiles measured at different locations downstream a slope break, are shown in Figure 5. Here, the persistence of long wave valleys at similar distances from the channel wall are associated with incipient longitudinal features similar to aggradational gullies observed in continental slopes.

IMPACT/APPLICATION

The laboratory experiments have clearly shown the capability of turbidity currents for producing longitudinal small-scale bedforms such as ripples as well as long-wavelength antidunes. Our understanding of the mechanics of bedforms in continental margins until now has been rather limited and full of speculation as observed in the recent EUROSTRAFORM meeting held at Winchester, United Kingdom. We hope that this work will facilitate both the interpretation of the geologic record as well as the design and placement of submarine structures on stable sediment deposits.

TRANSITIONS

The STRATAFORM program integrated field observations, laboratory experiments, and numerical modeling. Knowledge about the nature and dynamics of bedforms is crucial to the successful application of hydrodynamic models of turbidity currents, debris and mud flows in the submarine environment as well as for the interpretation of the geologic record. Turbidity currents could also play an important role in the scour around and burial of objects such as pipelines and mines. ONR's Mine Burial Program will also benefit from this research.

RELATED PROJECTS

We are currently preparing to conduct a set of ONR-funded experiments using the MARGINS tank in collaboration with Prof. Aaron Packman from Northwestern University. The goal of this work is to assess the impact of water chemistry on the dynamics of turbidity currents and their deposits.

REFERENCES

Fedele J.J. and Garcia M.H., 2001. Sediment Waves and Gullies created by Turbidity Currents. *American Geophysical Union, Margins Chapman Conference*. Poster Presentation; Ponce, Puerto Rico, June.

Fedele J.J. and Garcia M.H. 2001. Bedforms and Density Underflows in the Marine Environment. *2nd IAHR Symposium on River, Coastal and Estuarine Morphodynamics*, , Obihiro, Japan, September.

Murray A.B. and Paola C. 1986. A cellular model of braided rivers. *Nature*, 371, 54-57, 1994.
Parker G., Fukushima Y. and Pantin H., 1986. Self-accelerating turbidity currents. *J. Fluid Mech.*, 171, 145-181.

Spinelli G.A. and Field M.E., 2001. Evolution of continental slope gullies on the northern California margin. *J. Sedimentary Research*, 71, No 2, 237-245.

FY 2002 PUBLICATIONS

Fedele, J.J and Garcia, M.H., 2001. Alluvial Roughness in Streams with Dunes: A Boundary-Layer Approach, chapter in "River, Coastal, and Estuarine Morphodynamics, G. Seminara and P. Blondeaux, Editors, Springer-Verlag.

Choi. S.U., and Garcia, M.H., 2001. Spreading of Gravity Plumes on an Incline. Coastal Engineering, 43(4), 221-237.

Choi. S.U., and Garcia, M.H., 2001. K-Epsilon Turbulence Modeling of Density Currents Developing Two-Dimensionally on a Slope. Journal of Hydraulic Engineering, 128(1), 55-63.

Nino, Y., Lopez, F., and Garcia, M.H., 2002. Threshold Condition for Sediment Entrainment into Suspension, Sedimentology, in press.

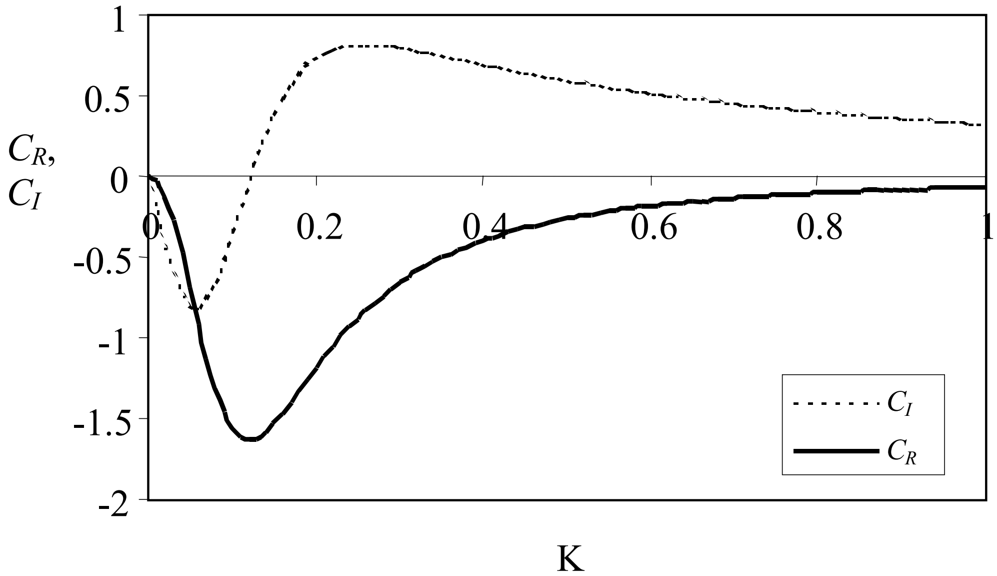

Figure 1. Components of the celerity of a bed perturbation. Density Current, four-equation model.

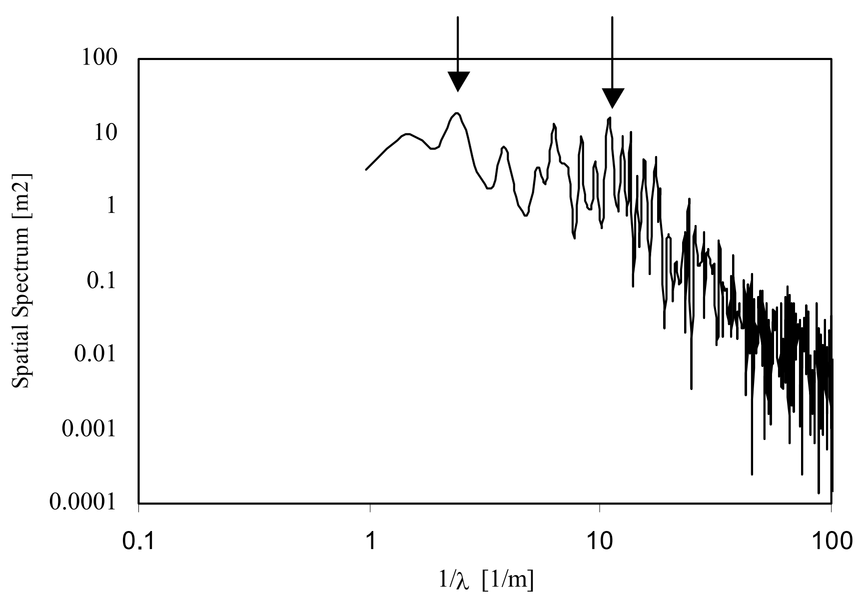

Figure 2. Spatial spectrum of longitudinal bed profiles for turbidity currents, with two characteristic bedforms: long wavelength antidunes, and ripples.

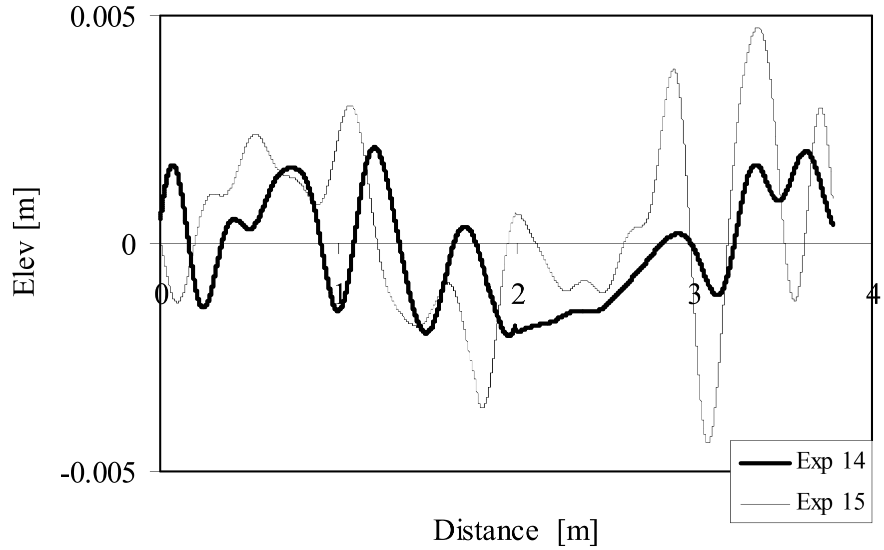

Figure 3. Long, upstream-migrating sediment waves resulting from successive supercritical turbidity currents

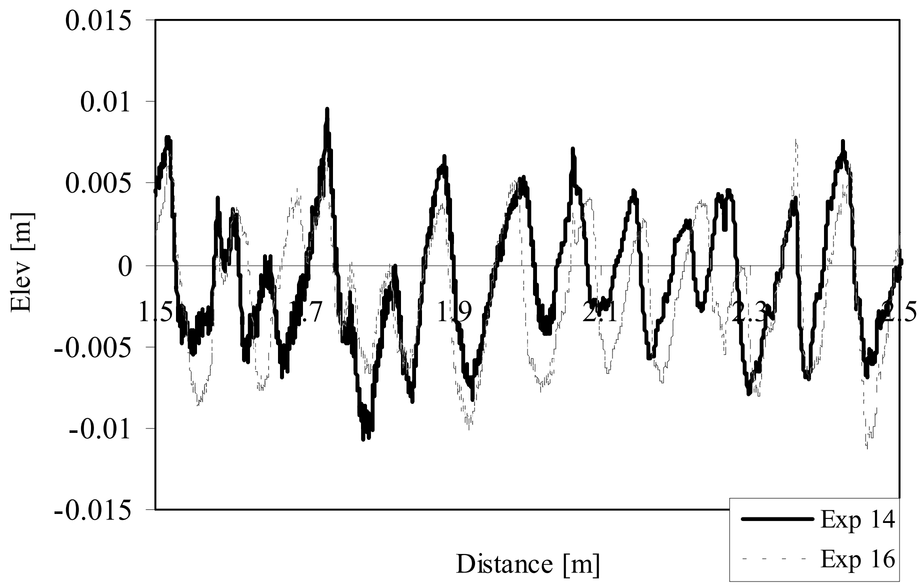

Figure 4. Downstream-migrating ripples for turbidity currents. (note that a long wave is observed as well, together with changes in ripple characteristic according to their position on the long antidune)

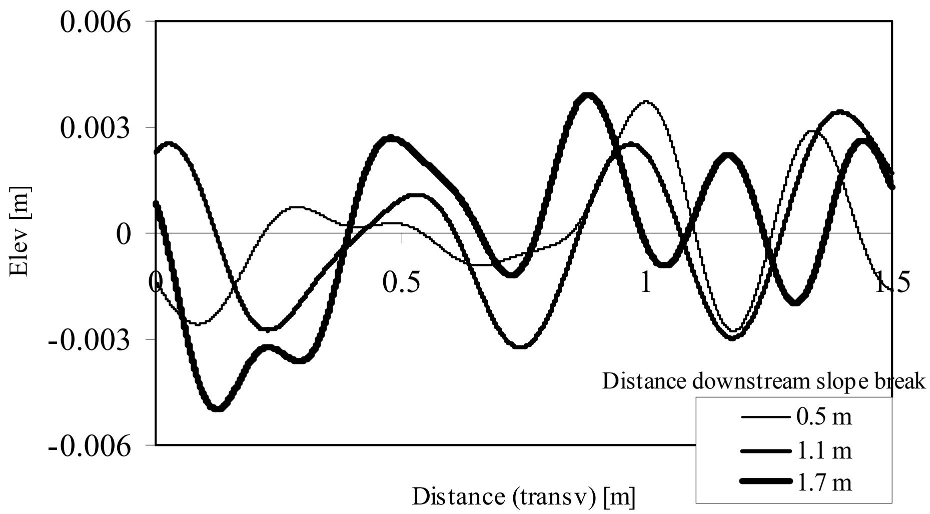

Figure 5. Transverse profiles (filtered) at different locations downstream a slope break.